SEMI-ANNUAL TECHNICAL SUMMARY REPORT

FOR

DATA ANALYSIS AND TECHNIQUE

DEVELOPMENT CENTER

DATDC REPORT NO. 28

23 August 1962

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ARPA Code No. 8100

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TABLE OF CONTENTS

INTRODUCTION

This report is the first Semi-Annual report covering work performed under contract AF 33(657)-7427, project VT/2037 in the period 15 October 1961 to 1 August 1962. It is composed of three parts corresponding to the three basic tasks of the work statement. For parts A and B, the work performed is outlined in the categories of the appropriate work statement tasks and sub tasks. For part C, operation of the Center, the work is outlined in the general categories of: Results, Status of Analysis Tools and Programs in process.

TASK -A- DEVELOP ANALYTICAL TECHNIQUES AND ANALYZE DATA PRIOR TO ESTABLISHMENT OF THE DATA ANALYSIS AND TECHNIQUE DEVELOPMENT CENTER

1. Conduct mathematical analyses of seismic wave generation, propagation and detection, leading to the determination of methods for extracting the maximum useful information from seismic data recorded from U.S. nuclear explosions (operation NOUGAT). Analyses conducted in this area include:

A. Higher Mode Structure of Seismograms

The purpose of this analysis is to detect differences in relative excitation of the high modes surface waves by sources of different depths. Spectral analysis of long-period records from the VT/078 stations of ANTLER were utilized, selecting those time intervals corresponding to propagation from the NTS to the stations at group velocities at which the Rayleigh modes are propagated.

Because of rapid dispersion, the presence of higher modes should show up in the spectra as reasonably sharp peaks in the frequency region below about 1 cps. Preliminary results showed three (3) conspicuous peaks at roughly 8½, 4 and 2½ seconds period, about the right places for M21, M22 and M13. There was an indication of a broader peak at about 20 seconds period, when the fundamental Rayleigh mode should come.

Theoretical computation of the dispersion curves for two structures, one corresponding to the Central U.S. and the

other to the trans-Sierra structure applicable to the NTS VT/078 stations, were made. Also, records were filtered through bands centered at the spectral peak periods to verify and locate the dispersed wave trains Work was done to augment a Rayleigh Wave Program for computation of mode amplitudes as a function of depth Preliminary results were encouraging Energy was found in modes in the band 1 - 1/10 cps, which lies between the response peaks of the long and short period instruments.

Additional analyses are being performed on signals traversing stations east of the rockies.

B. Optimum Spectral Operators

The purpose of this analysis is to find systematic differences in the spectra of waves generated by different classes of events. Digital computations were performed, using data from a 3 December 1961 explosion and a Long Beach earthquake.

Analog spectra of long samples of earthquake and shot events were too detailed for this study. Analog spectra of extremely short samples proved to be inaccurate with non-automatic tape editing equipment. Consequently, efforts were turned to developing digital methods

C. Statistical Study of Pattern Recognition of First Motion Study

This work was undertaken on the premise that an estimation of a given distribution of first-motion directions for a seismic event might serve as an indicator of the type of source. A statistical test was set up for the hypothesis that the source was an explosion based on only the probability of detecting first motion at each station the number of reporting stations and the number of compressional and rare factional first motions. Preliminary results indicate that a useful statistical test will require very considerable further effort and the work has therefore been set aside in favor of higher priority items.

D. Effect of Velocity Gradient in the Upper Mantle on Amplitude of P_n

The purpose of this analysis was to determine the feasibility of computing the effect on P_n waves of positive

and negative velocity gradients in the upper mantle. A short study was conducted and the results were not encouraging, owing to theoretical complexities. An attempt could be made to solve the basic field equations of elasticity adopted as necessary to include the effects of the velocity gradient. At the time this was not technically possible because an analytical representation of the velocity gradient leads to intractable partial differential equations, and a step function representation of the velocity gradient leads to intractable boundary conditions. It was concluded that this analysis should be done on a research basis, thus allowing more time for study. No further work has been done in this area.

2. Develop methods and techniques for machine analysis of seismic data from explosions--:

In this area, work involved a determination of the equipment needed, a collection of computer programs in existence and being developed and integration into the proposed system of the DATDC the known methods and techniques of machine analysis, plus development of new machine analysis methods and techniques.

AFTAC provided vital support in polling VELA program participants for lists of available digital computer programs. A study was made of this information and of program lists from other sources (the users' organizations of different computer manufacturers - SHARE, etc.). From this study a classification system was prepared of the useful programs and subroutines which should be used in performing this task.

The computer programs selected and the status of their collection, modification and checking were reported on 9 March 1962 and 6 April 1962 in the monthly progress reports for February and March. This information as of 12 June 1962 reported on 11 June 1962 at the monthly project review meeting. Appendix A gives a list of the computer programs selected and the status of their collection, modification and checking as of 1 August 1962.

The methods and techniques arranged for analog machine analysis fell into two basic categories:

A. Preparation of Data for Analysis

This area included such items as calibrated oscillograph reproduction of prime magnetic tapes, and copying magnetic tapes (reel-to-loop).

B. Data Analysis

This area included multi-channel filtering, computation of power spectral density, similarly for cross spectral density (to define the amplitude and phase relationships), and summing of signals and noise. Methods were also developed for computing PSD of signals by parts. A small analog computer (EAI-TR-10) was also rented and used experimentally.

3. Analyze seismic recordings supplied by the Government from U.S. nuclear explosions, and other appropriate seismic sources. Paste-ups of magnetic tape playbacks for shot records were prepared and submitted for immediate use. The first data were received during December 1961 in the form of a magnetic tape containing the seismograms of ANTLER as recorded at 5 LRSM and two VT/078 field stations.

New photographic displays for ANTLER were made with amplitudes equalized by the cube of shot-station epicentral distance; arrival times on the vertical component were aligned by subtracting ($\Delta/8.1$) from the true arrival time, and on the horizontal components by subtracting ($\Delta/3.5$) from true arrival time.

The purpose of these paste-ups was to get something done for a comparative study of the records and to establish a basis for study of necessary control requirements.

The paste-ups consisted of three channels, short period vertical, radial and transverse for all stations. Long period channels were not recorded for ANTLER.

Later, data were received on NTS shots, FISHER and GNOME. AFTAC requested that three (3) component seismograms be prepared and submitted in order that they could be distributed throughout the VELA program. These seismograms were to give the vertical, transverse and radial playouts for each station with the seismograms photographically reduced 5 cm per 10 sec. The playouts were made on equipment obtained from the VT/078 project but photographic reproductions had to be made using outside services.

The first NTS shot analysis assigned to the DATDC was DORMOUSE, detonated on 30 June 1962. For the purposes of the preliminary report, arrival times, amplitudes and residuals were determined. These results were based on the 35mm film records and on three-component play-outs from the magnetic tape.

The films were found best for determining the first arrivals and the play-outs best for the later arrivals. It was very useful to have both high-gain and low-gain play-outs, since large phases invisible on the film because of low trace intensity could often be found on the tape playbacks.

The procedure used for amplitude calculation was to determine a magnification at 1 cps for each component from the ball-lift calibrations, correcting for operational attenuation setting variations and for seismometer damping. Trace amplitude in millimeters was converted into particle velocity in millimicrons/second using this magnification factor and correcting for the response of the seismometer. "Periods" for each phase pick were determined from the time between successive peaks, troughs, or zero crossings.

Analysis assignments were received for NTS shots CHINCHILLA and CODSAW, detonated 19 February 1962. Preliminary reports on these two shots were based on the 35mm film records. These reports were less detailed than the DORMOUSE Report, being limited to a study of arrival time, residuals and amplitude of P_n.

Generally, the data gathered for CHINCHILLA and CODSAW agreed with the data for DORMOUSE. An interesting observation was that for both CHINCHILLA and CODSAW there was an apparent cave-in a short time after the detonations, causing after-shocks with phases consistent to those of the original events. These after-shocks will be examined in detail and reported on in the final reports.

In order to properly perform the work required under this section the equipment obtained from the VT/078 project proved to be inadequate for the digital programming requirements. Studies were made of possible sources for A/D Conversion and STL in Los Angeles was selected to do this work.

Early work included a successfully digitized part of an ANTLER record and a Geotechnical timing channel and gave output in the form of a gapped 7090 tape which could be read by the 1604 computer (the computer selected for the DATDC - explained in Task B - 2). The results were encouraging in that the method gave an accurate measure of relative time.

Later work included digitizing selected portions of the GNOME and DORMOUSE events and provided a magnetic tape which would be used by the 7090. A 1604 program read this tape and put the data in the proper format for use with DATDC subroutines.

In conjunction with the A/D conversion work being performed, outside computer time was utilized in order to process A/D data from 7090 to 1604, modify selected programs received from other VELA participants to work on the 1604 library tape to program the 1604 data processing system FORTRAN compatibility between the IBM 7090 and CDC 1604. check out new programs to manipulate digitized data obtained from A/D conversion. checkout various operating procedures for the DAIDC train DAIDC computer operators and test the CDC FORTRAN moniter for operating defficiencies.

This work was performed satisfactorily and further studies were made concerning other outside A/D conversion outlets after the DAIDC moved to Alexandria, Virginia, after which a 160A plotter would be available and the A/D conversion procedures could be changed to conform with less exacting requirements Also, studies were made on the program to obtain an in-house A/D conversion capability, to be implemented under Task C.

4. Prepare reports describing the analysis procedures and the scientific conclusions reached as a result of work accomplished under paragraphs (1), (2) and (3) of this section.

Reports, written and verbal, were submitted to AFTAC concerning all phases of the work performed during the period of Task A - 16 October 1961 through 30 April 1962. See Appendix B for a listing of reports submitted.

TASK -B- DESIGN AND ESTABLISH A DATA ANALYSIS AND TECHNIQUE DEVELOPMENT CENTER

Basically, the work called for under this task requires specification of people, machines and interactions of these people and machines. The revised Design Report submitted 17 August 1962 covers in specific details the recommended systems, procedures and functions leading to a successful accomplishment of the objectives strived for under this contract.

Following is a discussion of the assigned sub-tasks for this task, with the discussion being merely an abstract of the material contained in the Design Report:

1. Design a data processing system for manual and machine analysis of seismic data to accomplish the work specified under Task C:

It will be the function of the DATDC to store and analyze data and to conduct research on and evaluate detection and identification techniques. This function cannot be performed without equipment to handle the data, personnel to give direction to the analysis program and personnel to carry out the analysis and put it into understandable form. The Center will consist of groups (called sections) to carry out this concept and an efficient and successful operation will be dependent on smoothly interacting groups making use of one another's talents. Figure 1, (DATDC operating concept - Figure A2-1, Design Report), shows this concept and it can be noted that it results in a kind of "input-output transfer function" for the entire Center, and further that several internal "feed-back loops" exist to assure cross-fertilization and prevention of duplication of work. Also, there are no "dead-ended" groups working in isolation which, if existent, might work on techniques of low reward potential.

Figure 2, (Design Report Figure A2-2), shows the organization of the DATDC and the manpower requirements to perform the functions required under Task C of the work statement.

The equipment needed to operate the data handling and processing system is discussed in B-3.

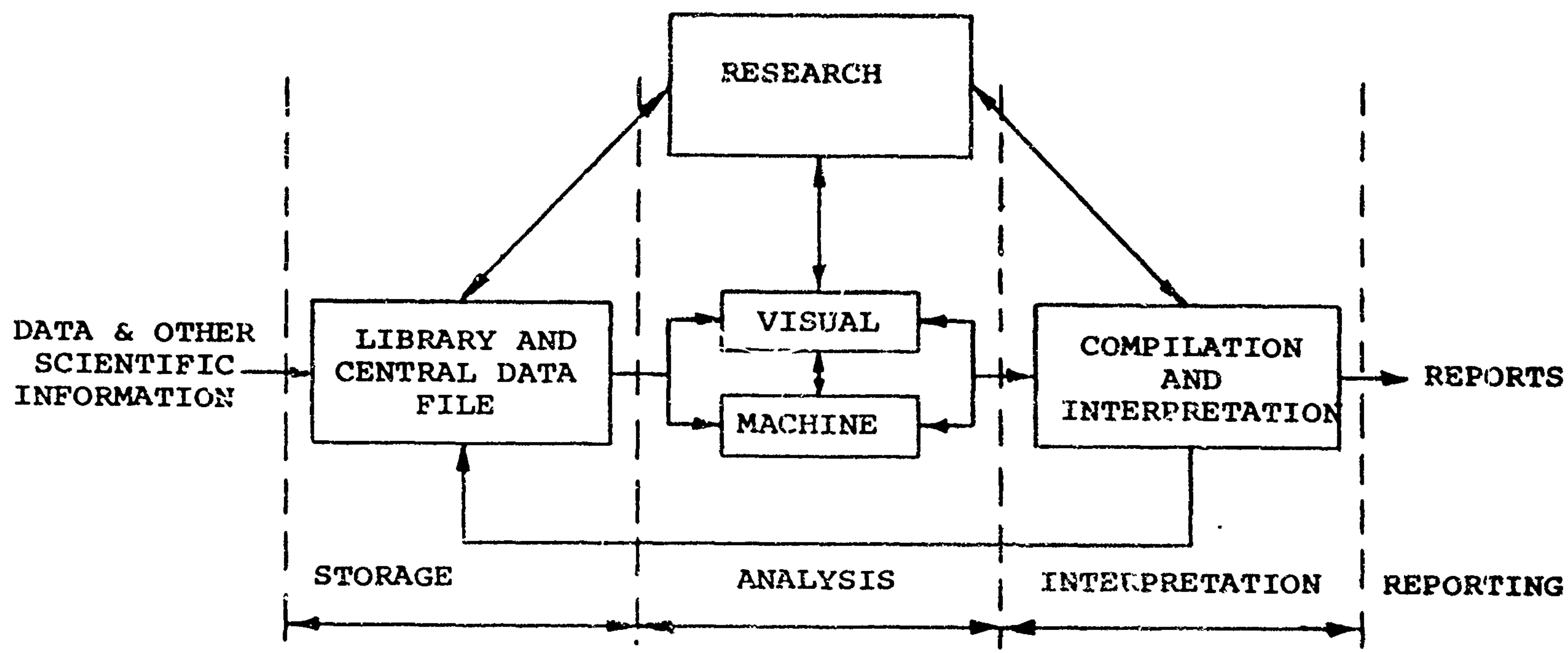
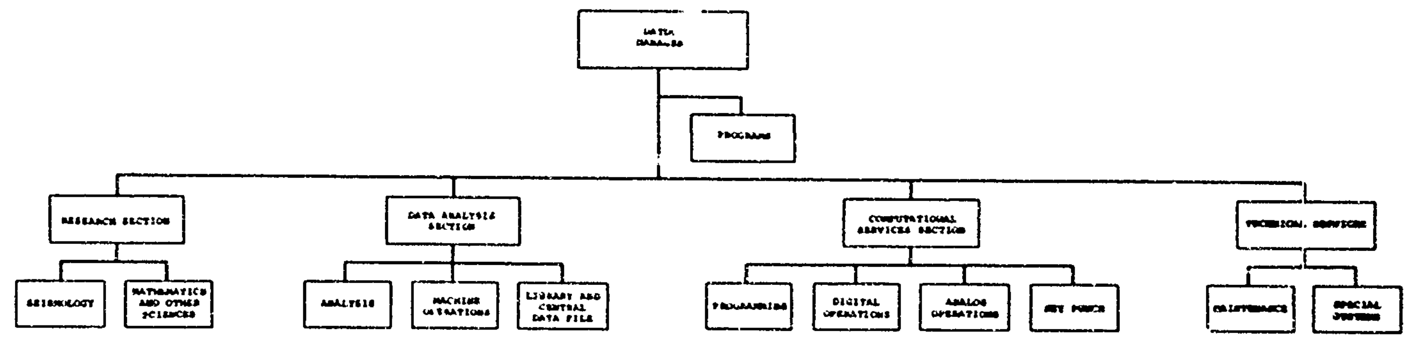


FIGURE 1 DATDC OPERATING CONCEPT



WORK STATEMENT TASK NUMBER	REQUIRED FUNCTION	SEISMOLOGY	MATHEMATICS AND OTHER SCIENCES	ANALYSIS	MACHINE OPERATIONS	LIBRARY AND CENTRAL DATA FILE	PROGRAMMING	DIGITAL OPERATIONS	ANALOG OPERATIONS	KEY PUNCH	MAINTENANCE	SPECIAL EQUIPMENT
1	MAINTAIN A CENTRAL DATA FILE AND FURNISH RECORDINGS OR PROCESSED DATA TO OTHER VELA PARTICIPANTS AS APPROVED BY THE AFTAC PROJECT OFFICER.					1 LIBRARIAN 2 CLERKS						
2	DESIGN AND DEVELOP NEW ANALYTICAL TECHNIQUES AND PROCEDURES FOR PROCESSING SEISMOLOGICAL DATA	2 SEISMOLOGISTS	1 SR. MATHEMATICIAN 1 NUMERICAL ANALYST									
3	ANALYZE AND EVALUATE DATA FROM EXPLOSIONS AND FROM SELECTED EARTHQUAKES.	1 SEISMOLOGIST		2 GEOPHYSICISTS 1 JR. GEOPHYSICISTS 3 ANALYSTS	3 TECHNICIANS 1 JR. TECHNICIAN		3 PROGRAMMERS 2 CODERS	2 MACHINE OPERATORS	2 ANALOG PROGRAMMERS/ OPERATORS	1 KEY PUNCH OPERATOR		
4	COMPILE AND REPORT BASIC DATA FROM EXPLOSIONS AND EARTHQUAKES, TO INCLUDE THE VARIATION OF AMPLITUDE WITH DISTANCE AS A FUNCTION OF FREQUENCY, TRAVEL TIMES OF BODY AND SURFACE WAVES, VARIATION OF AMPLITUDE WITH YIELD OF EXPLOSION IN [illegible], WAVEFORM CHARACTERISTICS, AND OTHER INFORMATION AS SPECIFIED BY THE AFTAC PROJECT OFFICER.	½ SEISMOLOGIST		1 GEOPHYSICIST								
5	EVALUATE EXISTING IDENTIFICATION CRITERIA, AND DEVELOP NEW CRITERIA, FOR DISTINGUISHING BETWEEN SEISMIC WAVES FROM NATURAL AND ARTIFICIAL SOURCES	1 SEISMOLOGIST	1/3 SYSTEMS ENGINEER 1/2 MATHEMATICIAN	1 JR. GEOPHYSICIST								
6	DETERMINE THE DETECTION AND IDENTIFICATION CAPABILITIES OF STATION NETWORKS TO INCLUDE THE EFFECT OF VARIATION IN SUCH PARAMETERS AS SPACING, EQUIPMENT AND BACKGROUND NOISE LEVELS		1/3 SYSTEMS ENGINEER 1 JR. MATHEMATICIAN									
7	SPECIFY DATA PROCESSING TECHNIQUES, PROCEDURES AND EQUIPMENT REQUIRED FOR THE ANALYSIS [illegible] VARIOUS NETWORKS CONSIDERED [illegible] ABOVE WHEN REQUESTED BY THE AFTAC PROJECT OFFICER		1/3 SYSTEMS ENGINEER									
8	COMPILE NOISE STATISTICS FOR LOCATIONS [illegible] BY SEISMIC STATIONS DURING THE [illegible] PROGRAM AND FROM OTHER LOCATIONS AS SPECIFIED BY THE AFTAC PROJECT OFFICER.		½ JR. MATHEMATICIAN	1 JR. GEOPHYSICIST								
9	DEVELOP PROCEDURES FOR CLASSIFYING EARTHQUAKES [illegible] ENERGY CONTENT AND DEFINE THE SEISMICITY OF [illegible] REGIONS IN TERMS OF TOTAL ENERGY RELEASED	½ SEISMOLOGIST	½ JR. MATHEMATICIAN									
10	CONDUCT MATHEMATICAL ANALYSES AND PROVIDE COMPUTATIONAL SERVICES TO OTHER VELA UNIFORM PARTICIPANTS AS APPROVED BY THE AFTAC PROJECT OFFICER		1/2 MATHEMATICIAN & SCIENTIFIC [illegible]							1 KEY PUNCH OPERATOR		
-	EQUIPMENT MAINTENANCE										3 GS ELECTRONICS TECHNICIANS	
-	SPECIAL EQUIPMENT SETUPS FOR SPECIFIC DATA PROCESSING EXPERIMENTS											1 ELECTRONICS ENGINEER
	TOTALS	5 SEISMOLOGISTS	4 MATHEMATICIANS 1 SYSTEMS ENGINEER	4 GEOPHYSICISTS 3 JR. GEOPHYSICISTS 3 ANALYSTS	3 TECHNICIANS 1 JR. TECHNICIAN	1 LIBRARIAN 2 CLERKS	3 PROGRAMMERS 2 CODERS	2 MACHINE OPERATORS	2 ANALOG PROGRAMMERS/ OPERATORS	1 KEY PUNCH OPERATOR	3 GS ELECTRONICS TECHNICIANS	1 ELECTRONICS ENGINEER

RESEARCH 10 — DATA ANALYSIS 14 — COMPUTATIONAL SERVICES 11 — TECHNICAL SERVICES 3

DATDC MANPOWER SUMMARY VS WORK STATEMENT TASKS

FIGURE 2

2. Design a system for cataloging and classifying incoming data which includes means for rapid access to significant data. Provision is to be made for storage of the raw data and for furnishing copies to other participants in the VELA Program:

The data coming into the Center can be divided into the following groups:

a. Station records on paper, film and magnetic tape.

b. Books, journals, reprints, reports, operators' logs associated with the seismograms and other written material.

c. Seismograms of events of particular interest, consisting of dubbed magnetic tapes, paper playbacks of these tapes, films, and paper records.

d. An earthquake and phase catalog, containing phase arrivals, amplitudes, etc., and earthquake locations.

Items of group (a) will be filed according to an inventory system, with cross-indexing to indicate whatever seismic events of particular interest are contained on any station record; this includes cross-reference to the special seismograms of group (c).

Items of group (b) comprise the standard scientific research library. In addition to the usual library card catalog, an automated system of abstract storage and key-word search will be instituted.

Items of group (c will be filed by the characteristics which make them interesting. They will be cross-indexed by a sufficient number of parameters of the events to allow catalog searching for specific types of interesting events; magnitude, epicenter location, nature of source, depth of focus, and the like, are such parameters.

The group (d) category consists only of the earthquake catalog cards generated by the Geotechnical Corp. for 10 LRSM stations. This catalog can be searched for earthquake location, depth of focus, magnitude, station distances, and station phase arrivals.

The present status of the Library and Central Data File is described under Task C following.

3. Obtain or prepare digital and analog computer programs for cataloging, processing and analyzing the data:

Previous work performed under this task is discussed in Task A - 2 and a list of the computer programs obtained and their status of 30 August 1962 is given in Appendix A.

4. Upon obtaining approval from the Government, procure and install the equipment necessary to operate the data handling and processing system:

Immediately upon award of the letter contract, detailed studies were started on determining the equipment necessary to perform the work called for under the work statement. Prior studies made by outside consulting firms and UES staff were up-dated and evaluated. In deriving the requirements for this equipment the following steps were taken:

a. The data inputs were listed and quantities estimated; the required functions to be performed were broken down into manageable groups; the required outputs were listed; the interfaces with other equipments and groups were listed.

b. Each function was interpreted in terms of the technique and type and quantities of equipment required for its performance.

c. An estimate was made of the type and quantity of personnel required to perform each function (see Task B-1 discussion).

The Data Analysis Section is the data hub of the DATDC and will conduct routine data analysis on blast and earthquake records and conduct data processing for research projects. The necessary equipment to perform these operations is as follows:

a. Visual Analysis
- film viewers (4)
- common engineering office equipment and supplies
- business machines (card punch, card sorter, and reproducer).

b. Machine Analysis - this equipment is divided into the following two groups, A and B:

GROUP A

Reel and tape loop recorders, wave analyzers, buffer amplifiers, recording oscillograph and filters.

Group A performs the primary function of the production of controlled amplitude playouts of records and determination of the frequency content of data (spectral analysis).

GROUP B

Two reel and one loop tape recorders, analog-to-digital converter, time code generator and time search mechanism.

Group B performs the primary function of feeding of data into the analog and digital computers. the preparation of copies of complete tapes, and the preparation of edited tapes.

The Computational Services equipment will consist of a CDC-1604 digital computer and a EAI 231-R analog computer, with the necessary peripheral equipment.

A digital computer offers versatility, accuracy, speed and division making capabilities. The DATDC digital computer should be able to handle programs generated by other organizations.

A small scale computer, the CDC 160A, will be used as a satellite system for input/output processing and analog-to-digital control.

The equipment complement includes:

1 - Central Processor with 32,768 word magnetic core storage, 48 bits/word.

8 - Magnetic Tapes

1 - Cord Read/Punch Unit

1 - Line Printer

1 - Plotter

1 - Satellite Computer with 8,192 words magnetic tape storage, 12 bits/word and two associated magnetic tape units

Since the primary source of incoming data to the DATDC will be analog magnetic tapes, an analog computer will be able to process these tapes directly in some cases. An analog computer can perform several operations on several channels of incoming data simultaneously while operating in real time, or 10X or 100X faster than real time. Moreover, the time required to set up new programs or change existing programs on the analog computer is short. Parameters can be changed in seconds; minor program changes can be made in minutes; and major changes can be made or new programs set up in a day or less.

Consequently, data processing operations whose parameters, criteria, and even the proper process itself are only vaguely defined can be modeled and tested quickly.

The analog equipment complement includes:

80 - Operational Amplifiers with 40 Summer - integrators, 35 summing amplifiers and 5 inverters.

100- Coefficient Potentiometers

12 - Multipliers

2 - Diode Function Generators

4 - Comparators.

The digital computer has been operational since 27 June. From 6 July to 20 August it has exhibited outstanding reliability with less than 2% "down-time."

The installation of the analog computer has been delayed to allow the manufacturer to make provision for electronic mode control.

5. Establish the Data Analysis and Technique Development Center:

A study made of space and environments showed the requirements to be approximately 15,000 square feet.

A search was conducted for facilities meeting these requirements in the vicinity of Alexandria, Virginia (midway between AFTAC headquarters and the Pentagon). No readily available facility in that area seemed suitable without

extensive modifications. Consequently, 14,900 square feet of space was leased in the Fidelity Building in Alexandria, a new structure to be completed in the Fall of 1962. Since the Fidelity is a new building, it will be designed to accommodate the DATDC. The DATDC will occupy the second and third floors. An inter-facility stairway will directly connect the second and third floors providing easy access for personnel and practical security control. JED administration and reception offices will be on the first floor. The facility will be well-lighted, air-conditioned, acoustically insulated in the computer areas and designed to permit efficient use of the equipment and facilities by the scientific and operating personnel.

The final floor plans, office and equipment layout and decoration details are completed. The builder has issued a construction schedule calling for completion in January 1963.

TASK -C- OPERATION OF THE DATA ANALYSIS AND TECHNIQUE DEVELOPMENT CENTER

INTRODUCTION

The technical work performed to Tasks A and B were discussed in accordance with the sub-tasks as set out in the statement-of-work to be done. Because much of the work called for under those two tasks was quite specific and identifiable against work statement tasks, it was discussed in that manner. However, the work accomplished to date under Task C, the operation of the DATDC, involves a close interaction and cross-fertilization of the various sub-tasks as set out in the work statement. Therefore, the following discussion of the technical work performed and the accomplishments attained under Task C is approached from the standpoint of over-all results.

This section is divided into the following grouping:

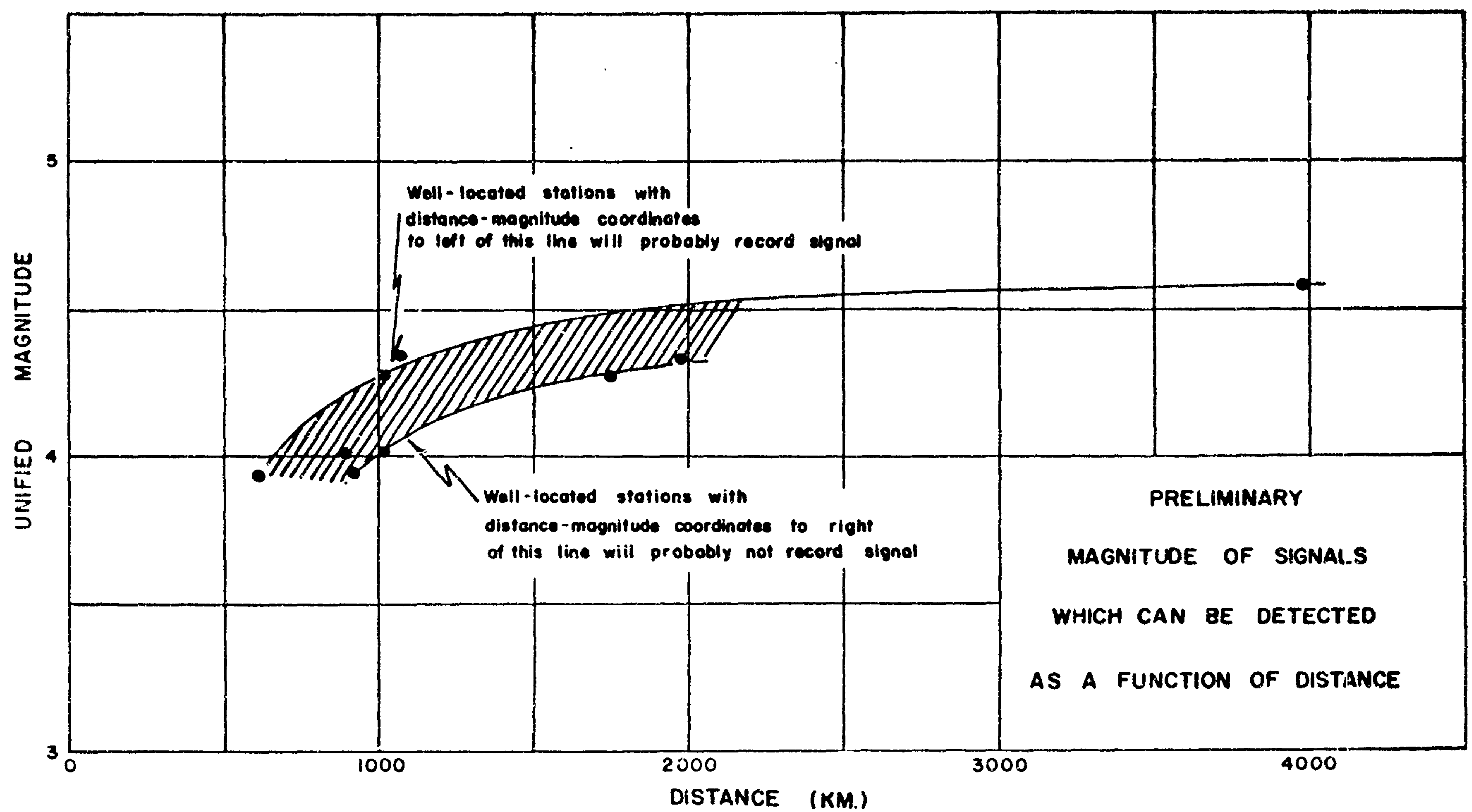
- Results
- Status of Development of Analysis Tools
- Status of Library and Central Data File
- Projects underway at the DATDC

1. Results

A. Magnitudes

It is possible, based on limited information to draw a preliminary pair of curves, one of which defines the maximum distance a signal of given magnitude is detectable with good probability, the other which marks the distance outside of which detection probability falls to quite a low value. Figure 3 has been constructed based on the average magnitude information from six shots at NTS.* No attempt has been made to separate the data by source environment. These conclusions should be considered as preliminary and would of course only apply to stations that are reasonably well-located in areas where the seismic noise level is not excessive.

* Dormouse, Codsaw, Chinchilla, Dormouse-Prime, Aardvark, Danny Boy.



UNIFIED MAGNITUDE
5
4
3
0
1000
2000
3000
4000
DISTANCE (KM.)
Well-located stations with
distance-magnitude coordinates
to left of this line will probably record signal
Well-located stations with
distance-magnitude coordinates to right
of this line will probably not record signal
PRELIMINARY
MAGNITUDE OF SIGNALS
WHICH CAN BE DETECTED
AS A FUNCTION OF DISTANCE

FIGURE 3

However, these results form a step in the direction of predicting the threshold capabilities of various networks of stations to reliably detect events as a function of magnitude.

There is considerable scatter in magnitude measurements of NTS events as recorded at various sites. An example of the variation is illustrated by the computed unified magnitudes for AARDVARK plotted vs distance. (See Figure 4). A portion of the scatter can probably be corrected by use of station or site corrections. The evidence is however, that the overall subject of magnitude determination retains sufficient variation to warrant further and extensive study. Such a study is being considered as a proposed analysis assignment.

B. P-Wave Attenuation Behavior

Results from the analysis of six events at NTS seem to verify that an inverse cube law of P-wave attenuation in the range from 300 to 1,000 kilometers is as good an approximation as any. This result conforms to measurements of amplitudes of Logan and Blanca reported by Romney[1] and that of earthquakes[2].

C. Long Period Wave Behavior

Visual analysis of seismograms from five (5) NTS low yield events recorded by the Long Period system of the LRSM show minimum evidence of long period data. Any such consistent radiation pattern behavior immediately suggests its possible use as an identification criterion, or at least as a diagnostic aid. It will, of course, be necessary to compare the long period behavior of correspondingly small earthquakes before conclusions can be drawn.

In addition, one higher yield event, AARDVARK, produced well-defined, long period data out to 3,500 kilometers. Consequently, the development of the technique must take account of its differing behavior as a function of shot magnitude. The data are presently being analyzed, particularly with reference to spectra and filtering to determine whether these processing techniques can be used to identify low amplitude, long-period data on shots which do not have well-defined visual data.

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[1] Romney, Carl, Amplitudes of Seismic Body Waves from Underground Nuclear Explosions - Journal of Geophysical Research V. 64 pp. 1489 - 1498. (1959).

[2] Gutenberg, B. and C.F. Richter, Earthquake Magnitude, Intensity, Energy, and Acceleration, Bull. Seis. Soc. Am. V. 46 pp. 105-145 (1956).

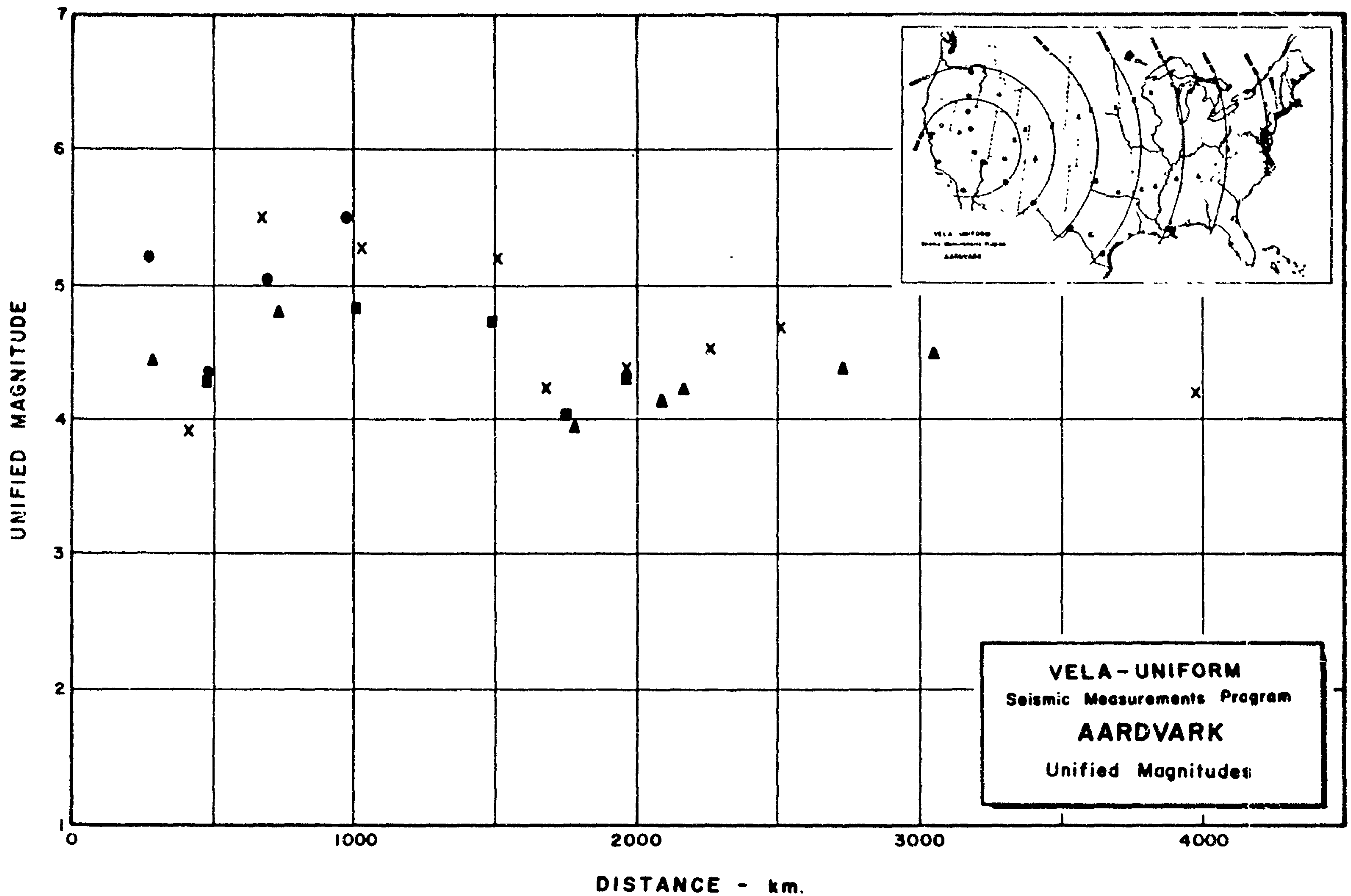
7
6
5
4
3
2
1
0
1000
2000
3000
4000
UNIFIED MAGNITUDE
DISTANCE - km.
VELA-UNIFORM
Seismic Measurements Program
AARDVARK
Unified Magnitudes

FIGURE 4

D. L_g Identification

Analysis of eight (8) events revealed the very considerable difficulty of determining the onset time of L_g. These results confirm the work of others. See for example, the comments on Thirlaway's paper on Depth of Focus Discrimination.* This effect is illustrated by the high degree of scatter of the L_g residual plots as submitted in various DATDC reports. Some present work is going on to study the vector sum of the horizontal components and the vector sum of all three components of the short-period instruments to determine among other things whether this process could aid identification of the L_g onset. Preliminary results suggest that it provides at least some help.

E. P_n Residuals

P_n residuals in the western United States show a smooth change with generally low values in sedimentary basins and high values in mountainous areas, as expected from the isostatic theory.

F. Spectra of Short Period Signals

Although spectra of an entire seismic event are more readily produced with analog equipment than spectra of parts of the signal, they are less useful. The spectrum of an entire signature is usually dominated by the shear wave portion of the record since it is generally both higher in amplitude and longer in duration. For this reason and because various suggested detection criteria have been concerned with relative energy in the P- and S-Groups it was decided to make spectra of the seismic signature by parts that can be conveniently separated by relative amplitude content. These parts are the P_n-group, the P_g-group, the S-group and the Surface Group. Results obtained have verified the validity of this decision.

Some results concerning spectra were included in the DORMOUSE final report. Considerable work and study is going on at the present time as to how best to present these rather complex data. Data from the Stations along the line between the GNOME Site and NTS are being used as a principal source in this study.

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*A consideration of H.I.S. Thirlaway's "Depth of Focus Discrimination within the Crust of First-Zone Distances," Vesiac Special Advisory Report, Number 1.

G. First Motion Criterion

Results generally confirm the conclusion that this criterion is highly subjective, varying with both the signal-to-noise ratio and with the human interpreter involved. Figure 5 is a copy of a group of first-motions of nuclear events as recorded at LRSM sites. These are included to illustrate the variation in data quality, and to serve as a basis for the following discussion.

With the understanding that quality of first motion is subjective, Figure 6 is a map of the United States on which is plotted the area within which well-defined first motion data were received. This area generally conforms to the basin area between the Sierra Nevada and the Rocky Mountains. It is conjecturally interpreted that the deepening of the MOHO under the mountain areas acts as a "barrier" to transmission.

One interesting conclusion is drawn from these data:

> The quality of first motion reception is a function of geological structure, and yet does not appear to be a significant function of explosive yield, at least in the yield range covered here of more than an order of magnitude.

H. Noise-Signal Product Study

An experiment was synthesized to determine whether the time of first motion of a seismic signal could be better determined by inspection of the integrated product of two or more channels from seismometers sufficiently physically separated so that the microseismic noise is dissimilar. This was accomplished by summing a known low noise signal into two such noise samples. A selection of signals of different first motion characteristics was also made. The results verified that this technique was of only limited value. All prime data were submitted to AFTAC in the form of suites of oscillograph records of the original and attenuated signals, the raw noise samples, the signals and noises mixed, their product and the final integrated function.

I. Crustal Thickness Results

The GNOME event in conjunction with NTS events constitute a reversed refraction profile. The results of a study of these data, in conjunction with results from the

FIRST MOTION
Definition

GOOD

QUESTIONABLE

NO EVIDENCE

FIGURE 5

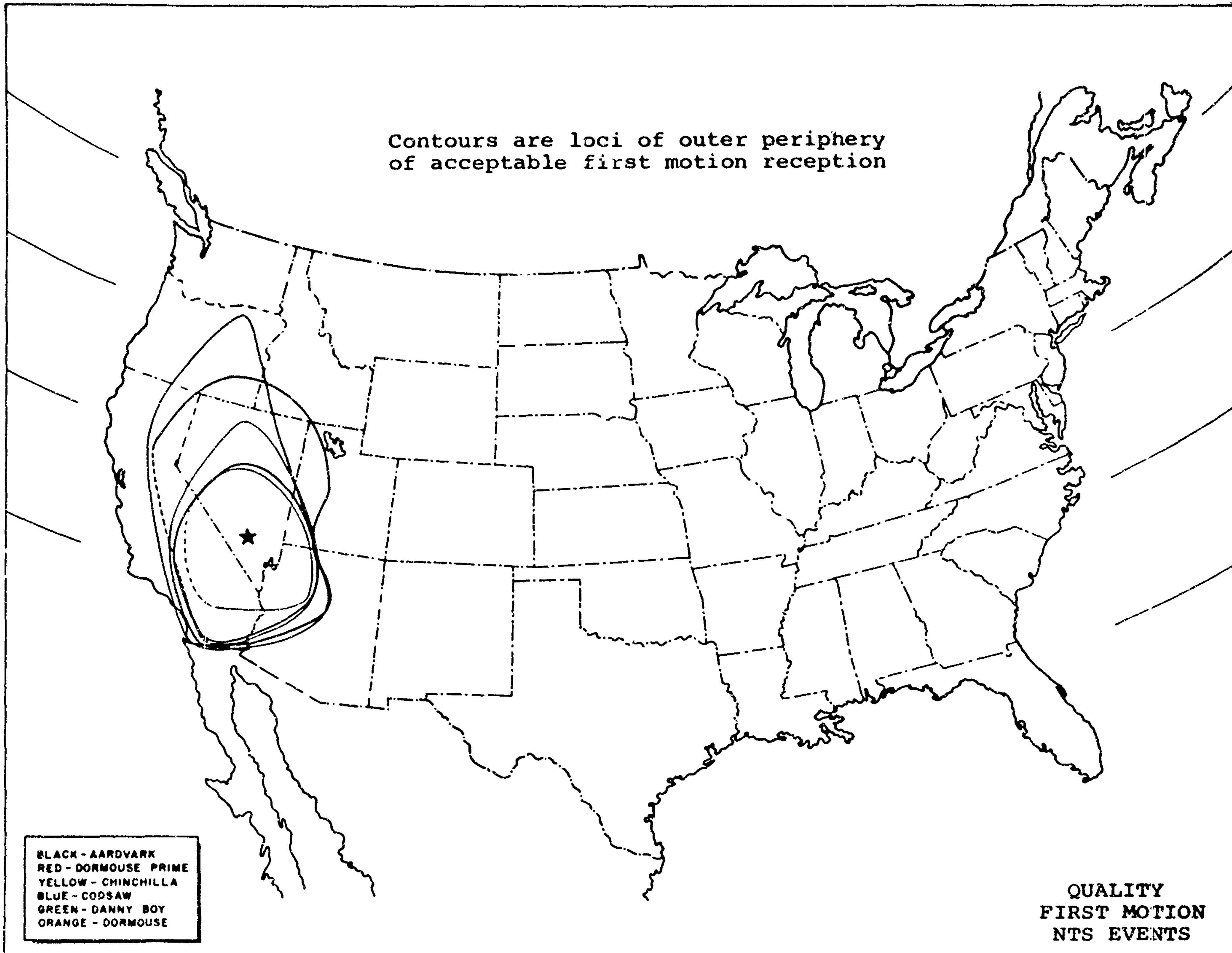
Contours are loci of outer periphery
of acceptable first motion reception
BLACK - AARDVARK
RED - DORMOUSE PRIME
YELLOW - CHINCHILLA
BLUE - CODSAW
GREEN - DANNY BOY
ORANGE - DORMOUSE
QUALITY
FIRST MOTION
NTS EVENTS

FIGURE 6

USGS Crustal Study Project in Nevada-California[1], are an approximate linear increase of P_n velocity from GNOME west to Pacific coast of California. Also the crustal thickness agrees with results reported by Press[2] for crustal thickness from Rayleigh wave phase velocity determinations.

These results are presently being extended to verify certain procedures used in the delay diagram technique of determining depth of focus. It has been concluded from this study that depth of focus determination can be improved in a calibrated area, that is one in which crustal thickness at the recording site and crustal velocities are determined. This study is also a part of the site study as it effects spectra.

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[1]United ElectroDynamics, Inc. - United Geophysical Corp., Preliminary Report, Seismic Studies of the Crustal Structure, California-Nevada Prepared for U.S. Department of the Interior Geological Survey, 1962.

[2]Press, F., Determination of Crustal Structure from Phase Velocity of Rayleigh Waves, Part I; Southern California, Bull. Geol. Soc. Am., 67, 1647-1648, 1956.

Press, F., Determination of Crustal Structure from Phase Velocity of Rayleigh Waves, Part II; San Francisco Bay Region, Bull. Seis. Soc. Am. 47, 87-88, 1957.

2. Status of Development of Analysis Tools

A modular digital processing system has been developed so that all digital programs are accessable to the user by simple control statements. This modularity concept gives the Center a quick reaction capability to unusual digital data processing requests and makes the digital computer available to all members of the DATDC.

Digital programs of general interest to VELA participants were requested and received. As necessary, these programs were modified to run within the CDC-1604 monitor system. By making use of programs which have already been written a large library of digital programs has been built up very quickly. (See Appendix A).

CDC FORTRAN 62 has been integrated into the digital system. FORTRAN 62 contains most of the latest improvements in FORTRAN and is more compatible with the new IBM 7090 FORTRAN.

After working with 4 contractors who were attempting to perform Analog-to-Digital conversion services for the Center, David Taylor Model Basin was selected on the basis of cost and convenience. A check on the accuracy of the conversion is accomplished by using the CDC-165 X-Y plotter to plot the digital output on the same scale as the original FM Tape playout. The X-Y plot is then laid directly over the original playout and a visual comparison can be made easily. A list of digitized data tapes (as of 1 August) is shown in Appendix C.

Contact was made with several individuals who have had extensive experience working with digital seismic data. Results of these meetings will determine the digital magnetic tape format which will be adopted by DATDC. This philosophy should minimize the communication problem between DATDC and other VELA participants.

A digital computer program has been written for processing linear array data. Data from WMSO linear array have been digitized and will be used as a test case for this program.

The EAI TR-10 analog computer has been used to develop techniques for doing auto and cross correlation, and for evaluating methods of introducing time delays. This work

will be continued and expanded on the EAI 231R analog computer which will be scheduled for delivery on August 30. The general status of the analog processing system and its capabilities have been covered in other reports.

3. Status of Library and Central Data File

The basic plan for the Library and Central Data File was discussed under task B-2. The actual status evolved in operation under task C is described below:

> The Library and Central Data File is a service organization of the Data Analysis Center. The objective of both operations is to render service with as little formality as possible.

LIBRARY

Magazines received by the Library are displayed, catalogued, routed and stored for future reference.

The bound books are catalogued by the Library of Congress method and are cross referenced for easy retrieval. There are approximately 175 books in the Library at this time. In addition to magazines and books there are abstracts, bibliographies, theses and translations readily available; all are processed in the same manner as the books.

Reports to be used in connection with the Data Analysis contract are also stored in the Library and all have been catalogued and cross referenced in much the same manner as the bound books. Accession lists have been prepared on both the books and reports.

Monthly acquisition lists are prepared and circulated to alert all personnel of the new publications as they are received by the Library. An adequate check-out system has been established for the purpose of controlling reports, books and periodicals.

CENTRAL DATA FILE

The Central Data File section of the Data Analysis Center is well established and has begun operation. There have been approximately 9,927 tapes (shot records and earthquakes) received from the Geotechnical Corporation and approximately 29,641 films received from the same source.

This constitutes records for the months of September 1961 through January 1962, and some for the months of May, June and July have also been received.

In addition to this bulk of material, there are also tape and film from TFSO and Coast and Geodetic Survey. All have been checked, placed on the shelves, arranged in order by station code and numerically marked by day and year. All storage cabinets and shelves have also been marked. The paper logs received on the tapes and films have been checked and filed in ring binders.

All tape, film and logs must be signed out when removed from the Central Data File area. A system for checking out material has been put into operation and is working efficiently. Only personnel responsible for the Central Data File and Library are allowed into this area. Programs for IBM key punching the tape and film are being worked on and this operation will start in the very near future.

MIT requested, and was sent, a digital tape of a 3 June 1962 earthquake recorded at WMSO Array. (Punched IBM cards to England).

4. Projects Underway at the DATDC

The following brief discussion outlines some of the programs in process at the DATDC. This listing is not complete but is suggestive of the scope of activities.

A. Component Synthesis

Synthesized traces consisting of the vector sum of the short-period horizontal records, and the vector sum of all three short-period records, are under study as aids in determining arrival time and amplitudes of later phases. Times, amplitudes, and magnitude estimates using the synthetic traces are under study and comparison with previous results.

B. Linear Array

A digital computer program for processing records from linear arrays has been written. Records from WMSO, TFSO, CPSO, and the Niagara, Wisconsin, arrays, for earthquakes and explosions have been received. Some WMSO data have been digitalized. Processing will start soon.

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B. Linear Array

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C. Inverse Filtering

An analog method of cross correlation is being established using two tape loop recorders. If the tape loops differ slightly in length, read out of one is gradually delayed relative to that from the other. The method works. However, synchronization pulses on extra tracks are necessary to calibrate the time delay.

D. Laguerre Transforms

A digital computer program has been written which provides amplitude, phase and power spectra for short transients. The method first expands the transient into a Laguerre series. Then, since the behavior of the Laguerre functions is known over all frequencies, the proper amount of each Laguerre response is added vectorially to find the total spectrum. The advantages are good convergence with a few terms and coverage from zero to infinity in both time and frequency. Detailed studies of Fourier-Laguerre transforms on analytical examples are underway to establish their accuracy and convergence properties. The immediate aim is to use them for digital computations of the spectra of individual phases of seismograms. About two dozen spectra have been computed in the past month. The programs will be available for routine use shortly.

E. Correlation Studies (Dormouse and Collapse)

The Dormouse records and those from the collapse 28 minutes later provide examples of recordings where the source and reference locations (and presumably the travel paths) are the same. If the complexities of seismograms are due primarily to travel-path effects, collapse records should agree with the originals. The correlation, however, is considerably less than 100%. Tests were conducted by squaring and integrating these records in the expectation that their envelopes would be in better agreement with each other. Here again, correlation was considerably less than 100%. Studies will continue to determine over what frequencies and what repeated experimental conditions such records do and do not correlate.

F. Power Spectral Density

Two FORTRAN programs have been coded to compute power spectral density (PSD) of a time series. The results are being compared with those of analog-computed PSD's. It appears that the two methods give comparable results and that the digital methods offer more useful information and greater flexibility.

G. Reading, Plotting and Printing Routines

Computer routines for the CDC 160A are being written to simultaneously plot and print, and read input cards and print. This will permit more efficient use of the 160A for input/output and as a satellite computer. The 160A will also be used in analog-to-digital conversion.

H. Digital System Integration

One digital programmer is working full time on digital system integration, writing routines for testing tapes, automatic accounting, priority interrupt, and increasing efficient use of the 1604. He is also responsible for keeping the system up-to-date and helping programmers to make the best use of utility programs.

I. Automatic Data Retrieval

One programmer is coding a routine to provide information on the inventory of the Central Data File. This program will list the contents of the file by station, date, or file number.

APPENDIX A

DIGITAL PROGRAM STATUS

30 August 1962

Code:		
	C	Complete and ready to use
	R	Requested, will be received by 1 July
	A	Awaiting checkout completion
	P	Programming in progress
	N	Requested but not received

Miscellaneous

C Earthquake location (ID-1); Bolt, Lamont
C Component resolution; Geer, UED
N Seismic travel times and amplitudes; Landisman and Sato, Lamont
C Component synthesis; Greer, UED
C Distance and azimuth; Turner, UED
A Phased Array; Flinn, UED

Filtering

N Filtering and clumping; Alsop, Lamont
C Digital filter routines; Alexander, CIT
N General purpose time series manipulation (BOMM); Munk, UCLJ
C Filtering subroutine (FILTER); Bogert, Bell
C Design of symmetric filter (COEFFT); Alexander, CIT

Spectral Analysis

C General harmonic analysis (FOURAN); Smith, CIT
N Fourier analysis; Alsop, Lamont
C Smoothed or unsmoothed sine or cosine transform (FOURTR); Bogert, Bell
C Tuckey Spectrum; UCLJ
A Fourier-Leguerre spectral anal; Dean, UED

Dispersion

C Rayleigh and Love wave dispersion (PV-7); Dorman, Lamont
N Synthetic seismogram; Brune and Dorman, Lamont
C Surface wave dispersion; Harkrider, CIT

Correlation

C Autocovariance (AUTCOV); Bogert, Bell
C Auto - and crosscovariance (CRSCOV); Bogert, Bell
N Convolution of symmetric filter with data (SYMCON); Simpson, MIT
C Filtering and decimating (FILDEC); Alexander, CIT

Matrix Routines

C Matrix inversion and linear equation solver; Flinn, UED
C Matrix inversion by Gauss Method; UTEX
C Matrix inversion; UCLJ

Least Squares Curve Fitting

N Least-squares line fitting (SCTLIN); Simpson, MIT
N Least-squares polynomial fit (E206); Share 772
N Least-squares arbitrary function fit (E208); Share 1076
C Least-squares polynomial fit; UCLJ

Output Plotting

C 160A plotter; UED
R Plotting; Alsop, Lamont
C Plotting; WDPC

Input-Output

C Output series title and values (OUTPUT); Bovert, Bell
C Read in series title and values (READIN); Bogert, Bell
C 7090-1604 Tape Format Conversion; AMES, UED

Series Manipulation

C Polar coordinates from rectangular coordinates (POLAR); Bogert, Bell
C Place zeros on both sides of series (CENTRE); Bogert, Bell
C Remove mean and linear trend (DETRND); Bogert, Bell
C Normalize sum of squares (NORMAL); Bogert, Bell
C Find extreme values of series (RANGE); Bogert, Bell
C Normalize amplitudes (SQUASH); Bogert, Bell
C Apply cosine taper (TAPER); Bogert, Bell
N Apply Hamming smoothing (SMOOTH); Simpson, MIT
N Remove best-fitting parabola (REMPAR); Simpson, MIT
P Form phase and component ratios; Greer, UED
C Form plot of results; Greer, UED
C Traveling energy; Greer, UED
N Traveling energy; Simpson, MIT

Instrument Response

P Correct for instrument response; Hickey, UED

Calibration

P Calibrate trace; Greer, UED

Math Analysis

C Double Precision Arithmetic; UCLJ
C Laguerre Polynomials; UCLJ
C Legendre Polynomials; UCLJ
C Chebyschev Polynomials; UCLJ
C Polynomial Rootfinder; UCLJ
C Extremum Seeker; UCLJ
C Interpolation or Extrapolation; UCLJ
C Double Precision Matrix Inversion; UCLJ
C Onepass Simulations Equations; UCLJ
C Eigenvalues and Vectors of Real or Complex Matrix (subroutine); UCLJ
C Eigenvalues-Eigenvectors of Real, Symmetric Matrix; UCLJ
C Multiple Regression Comprehensive Analysis; UCLJ
C Analysis of Variance; UCLJ
C Random Number Generator; UCLJ
C Lagrangian Interpolation
C Complex arithmetic package
C Trapezoidal Rule Integration
C Solu. of simultaneous linear equations; UTEX
C Multiple Regression and Correlation; UTEX

System Routines

C Magnetic Tape Trace; UCLJ
C Fortran Dump; UCLJ
C Fortran Trace; WISEG
C Real Time Clock; UCLJ
C Fortran Program Tuner; UCLJ
C Relocatable Binary tape load
C XY Plotter
C Control Data Corp. Assembly Program
C BCD to Octal conversion
C Tape merge and copy
C Memory Dump

APPENDIX B

DATDC REPORTS SUBMITTED TO DATE

DATDC REPORT NO.	TITLE	DATE
1	Monthly Progress Report, VELA T/2037-1 (November)	12/22/61
-	ANTLER Preliminary Paste-Up	1/2/62
2	Monthly Progress Report, VELA T/2037-2 (December)	1/8/62
-	Design Report	1/22/62
-	ANTLER Inverse Cube Calibrated Record Cross-Sections	1/24/62
3	Monthly Progress Report, VELA T/2037-3 (January)	2/8/62
-	Effect of Velocity Gradient in the Upper Mantle on Amplitude of P_n - Preliminary Report	3/1/62
-	GNOME Inverse Cube Calibrated Record Cross-Sections	3/2/62
-	DORMOUSE 3-Component Play-outs	3/2/62
4	DORMOUSE Analysis, Preliminary Report	3/4/62
5	Monthly Progress Report, VELA T/2037-4 (February)	3/9/62
-	GNOME and FISHER 3-Component Play-outs	4/5/62
6	Monthly Progress Report, VELA T/2037-5 (March)	4/6/62
7	CODSAW Analysis, Preliminary Report	4/8/62
8	CHINCHILLA Analysis, Preliminary Report	4/13/62

APPENDIX B (CONTINUED)

DATDC REPORT NO.	TITLE	DATE
9	Monthly Progress Report, VELA T/2037-6 (April)	4/24/62
10	Monthly Progress Report, VELA T/2037-7 (May)	5/31/62
11	Higher Mode Structure of Seismograms - Preliminary Report	6/1/62
12	Optimum Spectral Operators - Preliminary Report	6/1/62
13	Milestones Report	6/1/62
14	Monthly Progress Report - VELA T/2037-8 (June)	6/30/62
-	Noise-Signal Product Study	7/3/62
15	DORMOUSE Analysis Final Report	7/9/62
16	Linear Array Analysis - Status Report	7/6/62
17	Linear Array Analysis - Preliminary Report	7/13/62
18	Monthly Progress Report, VELA T/2037-9 (July)	8/2/62
19	Inverse Filtering of Seismic Signals - Preliminary Report	8/1/62
-	Earthquake Magnitude Studies	8/10/62
20	AARDVARK Analysis - Preliminary Report	8/14/62
21	DANNY BOY Analysis - Preliminary Report	8/14/62
22	DORMOUSE PRIME - Preliminary Report	8/14/62
23	CHINCHILLA Analysis - Preliminary Report (Revised)	8/14/62

APPENDIX B (CONTINUED)

DATDC REPORT NO.	TITLE	DATE
24	CODSAW Analysis - Preliminary Report (Revised)	8/14/62
25	Special Report - Preliminary Study of Velocity and Crustal Thickness, GNOME-NTS Area	8/10/62
26	Special Report - Preliminary Study - Crustal Thickness Determination, within First Zone Distance, from a Cal. of $P_n - P_g$, $P_g - L_g$ Intervals	(In press)
27	Design Report - Revised	8/17/62
28	Semi-Annual Technical Summary Report	8/22/62

APPENDIX C

LIST OF DIGITIZED TAPES

STATION	DATE	DIST (KM)	EVENT	TIME (GMT) INTERVAL	CONTENTS
WMSO	5-25-62	1600	White	1455-1510	T, L7, L6, L5, L2, L1
WMSO	6-03-62	5100	Earthquake	1509-1530	T, L7, L6, L5, L4, L3, L2
WMSO	6-03-62	4200	Earthquake	1732-1736	T, L7, L6, L5, L4, L3, L2
WMSO	6-10-62	7000	Dominic	1610-1618	L8, L7, L6, L5, L4, L3, L2, L1, L0, T
WMSO	6-20-62	2700	Earthquake	1323-1328	L8, L7, L6, L5, L4, L3, L2, L1, L0, T
WMSO	6-20-62	2700	Earthquake	1331-1336	L8, L7, L6, L5, L4, L3, L2, L1, L0, T
WMSO	6-20-62	2700	Earthquake	1348-1354	L8, L7, L6, L5, L4, L3, L2, L1, L0, T
WMSO	6-20-62	2700	Earthquake	1658-1664	L8, L7, L6, L5, L4, L3, L2, L1, L0, T
WMSO	6-27-62		Earthquake	1528-1535	L8, L7, L6, L5, L4, L3, L2, L1, L0, T
WMSO	6-27-62	1600	Haymaker	1803-1808	L8, L7, L6, L5, L4, L3, L2, L1, L0, T
WMSO	6-28-62	1600	Marshmallow	1700-1708	L8, L7, L6, L5, L4, L3, L2, L1, L0, T
FSAZ	1-30-62	500	Dormouse	1758-1805	T, ST, SR, SZ
FSAZ	1-30-62	500	Dor. Col.	1827-1833	T, ST, SR, SZ
SFAZ	1-30-62	600	Dormouse	1758-1805	T, ST, SR, SZ
SFAZ	1-30-62	600	Dor. Col.	1827-1833	T, ST, SR, SZ
SVAZ	1-30-62	720	Dormouse	1759-1806	T, ST, SR, SZ
SVAZ	1-30-62	720	Dor. Col.	1827-1834	T, ST, SR, SZ
MLNM	1-30-62	790	Dormouse	1759-1806	T, ST, SR, SZ
MLNM	1-30-62	790	Dor. Col.	1828-1834	T, ST, SR, SZ
TCNM	1-30-62	910	Dormouse	1759-1807	T, ST, SR, SZ
TCNM	1-30-62	910	Dor. Col.	1828-1834	T, ST, SR, SZ
LCNM	1-30-62	1025	Dormouse	1759-1808	T, ST, SR, SZ
LCNM	1-30-62	1025	Dor. Col.	1828-1836	T, ST, SR, SZ

Key to Contents Column Code

T = Timing
L = Element 1 of the linear array
ST = Short period transverse
SR = Short period radial
SZ = Short period vertical